Chapter 1
General

1-1. Purpose

The purpose of this new guidance is to standardize the process by which stability safety factors are established for use in the design and evaluation of the many different structures and structural components common to Corps of Engineer Civil Works Projects. The standardization process is based on the premise that the traditional factors of safety specified in the recent guidance for Corps structures, for the most part, provide adequate protection against stability failure. The standardization process recognizes, as did previous Corps guidance, that lower factors of safety can be assigned to those loads and loading conditions designated as *unusual*, or *extreme* where the probability of those loads and load conditions occurring during the life of the structure are significantly less than that assumed for *usual* loading conditions. The following elements were part of the safety factor standardization process :

- Traditional factors of safety specified in current Corps guidance documents were used as a basis for establishing new factors of safety which are re-formatted to be consistent with other Corps guidance that has probabilistic based requirements.

- The guidance incorporates past practices of assigning lower factors of safety, lower than those traditionally used for *critical* structures, to *normal* structures.

- The guidance incorporates past practices of categorizing maintenance and construction loads as *unusual* loads.

- The guidance defines in probabilistic terms the loading condition categories of *usual, unusual*, and *extreme* so as to provide standardization as to which category various structure specific loadings should be assigned.

- A general factor of safety equation is established by the guidance. In this equation a basic factor of safety, one traditionally used for critical structures, is modified by factors which account for loading probability, structure importance, and the knowledge of site information used in the stability analysis.

The above elements of the standardization process produce factors of safety that are similar to those specified for use in current Corps guidance related to specific structure types discussed in paragraph 1-2.b below.

1-2. Scope

a. General. This manual covers requirements for all aspects of static and pseudostatic stability analyses of hydraulic structures. When the stability requirements of this manual conflict with those in other Engineering Manuals or Engineering Technical Letters, the requirements of this manual shall govern. These requirements apply to all potential failure planes at or slightly below the structure/foundation interface. They also apply to certain potential failure planes within unreinforced concrete gravity structures. This manual defines the types and combination of applied loads, including uplift forces due to hydrostatic pressures in the foundation material. The manual defines the various components that enable the structure to resist movement, including anchors to the foundation. Most importantly, the manual prescribes the safety factors which govern stability requirements for the structure for various load combinations. These factors of safety in some cases are different from those required by previous guidance. The structures may be founded on rock or soil and have either flat or sloped bases. Also, guidance is provided for evaluating and improving the stability of existing structures.

b. Types of structures. The types of structures addressed in this manual include dams, locks, retaining walls, inland flood walls, coastal flood walls, spillways, outlet works, hydroelectric power plants, pumping plants, and U-channels. Pile-founded structures, sheet-pile structures, and footings for buildings are not included.

1-3. Applicability

This manual applies to all HQUSACE elements, major subordinate commands, districts, laboratories, and field operating activities having responsibilities for the design of civil works projects.

1-4. References

Required and related publications are listed in Appendix A.

1-5. Distribution Statement

Approved for public release, distribution is unlimited.

1-6. Background

a. General. Engineer Manuals published over the past 40 years have set stability requirements for the different major civil works structures and their various structural components. For sliding and bearing, the stability requirements have been expressed deterministically in terms of an explicit factor of safety that sets the minimum acceptable ratio of foundation strength along the most critical failure plane to the design loads applied to the failure plane. The analysis for determination of the resultant location in prior guidance has been termed an *overturning stability analysis*. This is a misnomer since a foundation bearing, crushing of the structure toe, and/or a sliding failure will occur before the structure overturns. This guidance replaces the term overturning stability analysis with resultant location.

b. Intent. The basic intent of the new guidance specified herein is summarized below:

(1) Provide new standard factors of safety as replacement for the somewhat variable factors of safety previously specified in other Corps guidance documents.

(2) Establish basic structural performance goals for each loading condition category.

(3) Provide tabular summaries of the structure-specific loading-condition check lists found in the other Corps guidance documents in order to properly categorize each loading condition as either usual, unusual, or extreme.

(4) Require the use of higher factors of safety for conditions where site information is not sufficient to provide a high degree of confidence with respect to the reliability of foundation strength parameters, loads information, and analytical procedures used in the stability analysis.

(5) Permit the use of lower factors of safety for existing structures when there is a high degree of confidence, based analysis are accurate.

c. Factors of safety. Factors of safety are needed in stability and structural analyses because of the potential variability in loads and material strengths. The factor of safety assigned to a particular stability design or investigation reduces the risk of unsatisfactory performance due to loads being greater than assumed for design and the risk of unsatisfactory performance due to material strengths being less than assumed for design. This guidance makes no attempt

to quantify the reliability of the safety factors prescribed for use in the design and evaluation of Corps structures other than that they are traditionally accepted values that when used with prescribed simple assessment procedures have produced structures which have performed satisfactorily for many years. The minimum-allowable safety factors described in this manual assume that a complete and comprehensive geotechnical investigation has been performed. Safety factors higher than the described minimums are warranted if uncertainties exist in the subsurface conditions or if reliable design parameters cannot be determined. When concerns about stability exist, the designer should take all measures necessary to quantify load and material strength variability and use the most comprehensive analytical tools available to evaluate the capacity of the structure to meet performance objectives.

d. Sliding stability. Sliding of a structure on its foundation represents the most difficult aspect of a stability analysis, especially in those instances where the foundation is jointed and sheared and where the strength properties vary throughout the foundation. The approach to evaluating sliding stability is one that uses the limit equilibrium method with the linear Mohr-Coulumb failure criterion as a basis for estimating maximum available shear strength. The greatest uncertainties in the analysis are those associated with shear strength determination. For dams and other critical structures, the limit equilibrium method specifies for the usual load condition category a minimum-acceptable factor of safety of two. This compares to previous guidance used by the Corps and current guidance used by other agencies involved in the design of dams that uses a shear friction approach with a minimum acceptable factor of safety of four. The lower factor of safety prescribed in the recent guidance for use with the limit equilibrium method is based on the premise that explorations and testing programs now used are more comprehensive and result in shear strength values that are much more reliable than those established for use in the design of older dams. The use of modern analytical tools is an additional reason for the lower safety factors. The guidance recognizes that there are foundations where design shear strength parameters are highly variable because foundation conditions change from one area of the foundation to another and because the foundation may be comprised of intact rock, jointed rock, and sheared rock all with differing shear / displacement characteristics and possibly with strain-softening characteristics which make overall strength a function of displacement. A combination of experience and judgment is necessary to confidently determine that the strength and load parameters used in the stability analysis will provide structures that meet performance objectives.

Increasing the level of confidence in the foundation strength parameters can be achieved by :

(1) Performing additional explorations and testing (which has been properly coordinated to represent expected loading conditions) to assure foundation design strength values are accurate.

(2) Increasing the conservatism in the selected design strengths to account for uncertainties in the in situ strength.

Increasing the level of confidence in the design loadings selected for the stability analysis can be achieved by :

(1) Performing additional hydrological studies, earthquake ground motion studies, barge impact studies, and any other studies that will assure the loads and load conditions used in the stability analysis are accurate and fall into the load-condition category assumed for the stability analysis.

(2) Increasing the conservatism in the selected design loads and load conditions to account for uncertainties that loads experienced by the structure will not exceed those assumed for design.

1-6. Coordination

Even though stability analysis is a structural engineering responsibility, the analysis must be performed with input from other disciplines. It is necessary to determine hydrostatic loads consistent with water levels determined by hydraulic and hydrological engineers. Geotechnical engineers and geologists must provide information on strengths and permeabilities of foundation materials. To ensure that the information is applied appropriately, it is important that the structural engineer

understand methods and assumptions used to develop this interdisciplinary data. The structural, hydraulic, hydrological, and geotechnical engineers and geologists involved in the design process are a team, sharing responsibility for all recommendations and decisions.